Performance of the Anti-Coincidence Detector on the GLAST Large Area Telescope

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Abstract. The Anti-Coincidence Detector (ACD), the outermost detector layer in the Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT), is designed to detect and veto incident cosmic ray charged particles, which outnumber cosmic gamma rays by 3-4 orders of magnitude. The challenge in ACD design is that it must have high (0.9997) detection efficiency for singly-charged relativistic particles, but must also have a low probability for self-veto of high-energy gammas by backsplash radiation from interactions in the LAT calorimeter. Simulations and tests demonstrate that the ACD meets its design requirements. The performance of the ACD has remained stable through stand-alone environmental testing, shipment across the U.S., installation onto the LAT, shipment back across the U.S., LAT environmental testing, and shipment to Arizona. As part of the fully-assembled GLAST observatory, the ACD is being readied for final testing before launch.

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INTRODUCTION – DESIGN REQUIREMENTS

The Anti-Coincidence Detector (ACD) is a subsystem of the Large Area Telescope (LAT) [1] on the Gamma-ray Large Area Space Telescope (GLAST) [2], scheduled for launch in late 2007 to study the high-energy sky. The ACD works with other LAT subsystems to identify and reject charged particles, which are 3-4 orders of magnitude more numerous than the gamma rays of interest.

In addition to its requirement for high detection efficiency for charged particles (0.9997), the ACD must reduce the possibility of self-veto from what is known as the backsplash effect. High energy photons detected by LAT create electromagnetic showers in the calorimeter. A small fraction of the low-energy photons (0.1 to few MeV) in the shower move backwards and can create a signal in the ACD if they produce a Compton electron. In some cases this signal cannot be distinguished from a charged particle signal, which indicates an event that must be rejected. This means that "good" γ-ray events, otherwise accepted, can be vetoed by this backsplash effect. As a result, LAT efficiency for γ-ray detection could degrade if steps are not taken to avoid this issue.

These performance requirements must be met by the ACD within the usual constraints of a space program, including low mass, survivability through launch conditions, and long-term operation in the temperature, particle, micrometeoroid and vacuum conditions of the space environment.

ACD DESIGN APPROACH

The detector of choice for charged particle anticoincidence is plastic scintillator with photomultiplier tube (PMT) readout. This combination has a long history of use in both accelerator and space applications. To suppress self-veto caused by backsplash, we segment the ACD by using 89 optically-isolated scintillator tiles, then ignore ACD hits that are not in line with the reconstructed point of entry for an incident gamma ray. Optimal segmentation was determined by simulations, based on accelerator measurements at CERN of the backsplash [3].

In order to reduce signal fluctuations (the principal origin of inefficiency), we need as much light yield as possible from the tiles, plus uniformity. Testing showed that 1 cm thickness of plastic scintillator is enough if we read out the signals with wavelength-shifting fibers spaced 5 mm apart. Two phototubes are used on each tile for redundancy. A complication of operating in the space environment is that we must minimize the gaps between segments while allowing for very significant thermal expansion/contraction. Scintillator tiles overlap in one dimension; in the other direction, the gaps are covered by ribbons of scintillating fibers.

An operational consideration is that minimizing backsplash and maximizing efficiency are competing requirements: Backsplash reduction implies high threshold, while high efficiency for particle detection implies low threshold. The current plan is that the on-board ACD threshold will be operated at a relatively high level, ~0.4 of the average signal for a minimum ionizing particle (mip). The ground analysis will have the capability of using a lower threshold to optimize the efficiency/backsplash tradeoff.

ASSEMBLED ACD PERFORMANCE

Total efficiency of a large-area detector like the ACD cannot be directly measured on the ground. No calibrated isotropic source of charged particles is available. As a way to confirm that the ACD meets its requirements, we measured performance for all individual flight detectors, as well as their positions on the structure, and sample efficiency measurements at various locations on the array, using comic ray muons as a source. The detector performance measurements were combined with ACD simulations to determine the average detection efficiency for singly-charged relativistic particles, as well as the final backsplash probability. Details are described in [4].

The key performance results are:

1. The ACD average efficiency exceeds 0.9998 (the requirement was 0.9997) with all components working as measured. The 0.9997 requirement can be met even if one set of ACD readout electronics (up to 17 of the 194 channels) does not work.
2. The backsplash at 300 GeV will remove fewer than 8% of the incident photons (the requirement was less than 20%) at the nominal threshold settings, giving substantial margin.

Following the assembly and performance testing of the ACD, the ACD has completed a series of additional tests, including standard suites of environmental tests:

- subsystem level testing at Goddard in the summer of 2005, before integration to LAT;
- at Stanford Linear Accelerator Center (SLAC) from August 2005 to May 2006, before and after integration to LAT;
- LAT environmental tests at the Naval Research Laboratory (NRL) in the summer of 2006;
- to date with LAT on the GLAST spacecraft, at General Dynamics in Arizona.

The ACD has demonstrated the required stability of performance through all these tests, over a long time interval. In particular, thermal vacuum testing has confirmed that the ACD measured detector performance improves at lower temperatures (closer to the expected operating temperature in orbit), offering additional margin. The ACD group and the rest of the LAT team look forward to the GLAST launch.

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